Designation: A 21 – 94 (Reapproved 1999)

Standard Specification for Carbon Steel Axles, Non-Heat-Treated and Heat-Treated, for Railway Use[1]

This standard is issued under the fixed designation A 21; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers nonheat-treated axles up to and including those 6½ in. (165.1 mm) nominal diameter at the center and heat-treated axles of all sizes for freight cars, passenger cars, and locomotives.

1.2 This specification is for axles with machined bodies. For axles with as-forged bodies, see Specification A 383.

1.3 The grades of carbon steel axles are as follows:

1.3.1 *Grade U*—Nonheat-treated.

1.3.2 *Grade F*—Double normalized and tempered. (All freight axles over 6½ in. (165.1 mm) nominal diameter at the center shall be Grade F.)

1.3.3 *Grade G*—Quenched and tempered.

1.3.4 *Grade H*—Normalized, quenched, and tempered.

1.3.5 Grades F, G, and H axles are used in heavy-duty service on locomotives, cars, and other equipment.

1.4 Typical designs for plain and roller bearing axles are shown in the *Manual of Standards and Recommended Practice* of the Association of American Railroads.[2]

1.5 Supplementary requirements are provided for use when additional testing or inspection is desired. These shall apply only when specified individually by the purchaser in the order.

1.6 The values stated in inch-pound units are to be regarded as the standard.

2. Referenced Documents

2.1 *ASTM Standards:*

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products[3]

A 383 Specification for Axles, Railway, Carbon Steel, Untreated for Export and General Industrial Use[4]

E 112 Test Methods for Determining Average Grain Size[5]

E 127 Practice for Fabricating and Checking Aluminum Alloy Ultrasonic Standard Reference Blocks[6]

E 381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings[5]

2.2 *Military Standards:*

MIL-STD-129 Marking for Shipment and Storage[7]

MIL-STD-163 Steel Mill Products, Preparation for Shipment and Storage[7]

2.3 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipments (Civil Agencies)[7]

3. Ordering Information

3.1 The inquiry, order, or contract for material under this specification shall include the following information:

3.1.1 Quantity (number of pieces),

3.1.2 ASTM designation and year of issue,

3.1.3 Grade,

3.1.4 Design and size,

3.1.5 Intended service, and

3.1.6 Supplementary requirements (if any).

4. Manufacture

4.1 *Process*—The steel shall be made by any of the following processes: open-hearth, electric-furnace, or basic-oxygen.

4.2 *Discard*—Sufficient discard shall be made to assure freedom from piping and undue segregation.

4.3 *Forging Practice*—The axles may be made direct from the ingot or from blooms. The total reduction from ingot or strand cast bloom to forging shall not be less than 3 to 1, unless otherwise specified.

4.4 *Cooling and Heating*:

4.4.1 After axle blooms are produced they shall be slow cooled in closed containers, hoods, or furnaces.

4.4.2 Blooms shall be reheated for forging in a manner which will prevent internal bursts and overheating.

4.4.3 After forging, axles shall be slow cooled in closed containers, covered conveyors, or in hoods. If axles (Grades F, G, and H) are heat-treated directly from the forging, they shall be slow cooled following the final heat treatment.

NOTE 1—After slow cooling, Grade U axles may be single normalized

[1] This specification is under the jurisdiction of ASTM Committee A-1 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.06 on Steel Forgings and Billets.

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[2] Obtainable from the Mechanical Division, Association of American Railroads, 1920 L St. N.W., Washington, DC 20036.

[3] *Annual Book of ASTM Standards*, Vol 01.03.

[4] *Annual Book of ASTM Standards*, Vol 01.04.

[5] *Annual Book of ASTM Standards*, Vol 03.01.

[6] *Annual Book of ASTM Standards*, Vol 03.03.

[7] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

in accordance with 4.4.4 and 4.5.2.

4.4.4 Axles (Grades F, G, and H) that are heat-treated directly from forging (*1*) shall be cooled below the transformation temperature or to approximately 1000°F (538°C) before any reheating operation and (*2*) must not be permitted to cool below 500°F (260°C) without slow cooling as defined in 4.4.3.

NOTE 2—As the temperature of the axles approaches the minimum of 500°F (260°C) a supplemental heat source may be necessary to assure an effective slow cooling cycle.

4.4.5 When properly vacuum-degassed steel is used, the slow cooling requirements of 4.4.1, 4.4.3, and 4.4.4 may be omitted but axle blooms must then be pile cooled.

4.5 *Heat Treatment*:

4.5.1 Axles for heat treatment shall be reheated gradually and uniformly to a suitable temperature to refine the grain structure.

4.5.2 *Normalizing*—After heating to a suitable temperature the axles shall be withdrawn from the furnace and allowed to cool in air. A furnace charge thus treated is called a normalizing charge. Cooling may be accelerated by increased air circulation which must be controlled to provide reasonably uniform cooling.

4.5.3 *Double Normalizing*—The procedure shall consist of two separate normalizing treatments. The second shall be performed at a lower temperature than the first treatment. A furnace charge thus treated is termed a double-normalizing charge. Cooling may be accelerated by increased air circulation which must be controlled to provide reasonably uniform cooling.

NOTE 3—A single normalizing treatment shall be permitted when all other requirements for Grade F are met.

4.5.4 *Quenching*—After heating to a suitable temperature the axles shall be quenched in a suitable medium under reasonably uniform conditions. A furnace charge thus treated is termed a quenching charge.

4.5.5 *Tempering*—Axles shall be reheated gradually to, and held at, a suitable temperature below the critical range and shall then be allowed to cool under suitable conditions. A furnace charge thus treated is termed a tempering charge.

4.5.6 Heat treatment may be performed in either batch-type furnaces or continuous furnaces.

4.6 *Straightening*:

4.6.1 Any straightening of axle forgings shall be done before machining and in such a manner as to leave the axle body free of injurious marks.

4.6.2 Straightening shall preferably be performed at a temperature no lower than 950°F (510°C). Straightening performed at a temperature lower than 950°F shall be followed by a furnace stress-relieving procedure or applicable heat treatment.

5. Chemical Requirements

5.1 *Chemical Composition*—The steel shall conform to the requirements for chemical composition shown in Table 1.

5.2 *Cast or Heat Analysis*—An analysis of each cast or heat shall be made by the manufacturer to determine the percentages of the elements specified in Table 1. The analysis shall be made from a test sample taken preferably during the pouring of the cast or heat. The chemical composition thus determined shall conform to the requirements in Table 1.

TABLE 1 Chemical Requirements

Element	Composition, %					
	Nonheat-Treated		Heat-Treated			
	Grade U		Grade F		Grades G and H	
	min	max	min	max	min	max
Carbon	0.40	0.55	0.45	0.59	. . .	. . .
Manganese	0.60	0.90	0.60	0.90	0.60	0.90
Phosphorus	. . .	0.045	. . .	0.045	. . .	0.045
Sulfur	. . .	0.050	. . .	0.050	. . .	0.050
Silicon	0.15	. . .	0.15	. . .	0.15	. . .

5.3 *Product Analysis*—An analysis may be made by the purchaser from one axle representing each heat. The chemical composition thus determined shall conform to the requirements of 5.1 subject to tolerances included in Table 2. The sample for these analyses shall be taken from one end of the test axle or full-sized prolongation at a point midway between the center and surface. If drillings are taken, they shall be obtained using a ⅝-in. (16-mm) diameter drill or turnings may be taken from a tension test specimen.

6. Mechanical Requirements and Tests for Nonheat-Treated Axles

6.1 At the option of the manufacturer, either drop tests or tension tests (but normally not both) shall be performed to qualify each heat of steel.

6.2 *Drop Test*:

6.2.1 The test axle shall be so placed on supports 3 ft (914 mm) apart that the tup will strike it midway between the ends. It shall stand without fracture five blows from a tup of 2240 lb (1016 kg) falling from a height H such that H in feet equals the square of the diameter of the axle at the center in inches, $H = d^2$. The axles shall be rotated through 180° after the first and third blows.

6.2.2 Before the axle is drop tested, the center shall be calipered to the nearest ⅛ in. (3.2 mm) and the height of drop in feet, to the nearest ½ ft, shall not be less than the square of the actual diameter at the center in inches.

6.2.3 The permanent set produced by the first blow shall not exceed that given by the following equation in which L = length of axle in inches and d = diameter of axle at center in inches:

$$\text{Permanent set, max, in.} = L/1.9d - d/2 + ½$$

6.2.4 The drop test requirements for AAR untreated standard plain bearing axles Classes A to E are shown in Table 3. Drop test requirements for AAR standard roller bearing axles, Classes B to E, are shown in Table 4. Class F and all other plain or roller bearing axles over 6½ in. nominal diameter at center are not subject to drop test (Section 1).

6.2.5 The permanent set is the difference between the distance from a straightedge to the middle point of the axle, measured before the first blow and distance measured in the same manner after the blow. The straightedge shall rest on the end collars or ends of the axle.

TABLE 2 Permissible Variations for Product Analysis (for Cross Section 100 in.^{2} (645 cm^2) and Under)

NOTE 1— Product cross-sectional area is defined as either:
(a) maximum cross-sectional area of rough machined forging (excluding boring),
(b) maximum cross-sectional area of the unmachined forging, or
(c) maximum cross-sectional area of the billet, bloom or slab.
Area taken at right angles to the axis of the original ingot or billet.

Element	Permissible Variations, Over the Maximum Limit or Under the Minimum Limit, %
Manganese	0.03
Phosphorus	0.008
Sulfur	0.008
Silicon	0.02

6.2.6 The temperature of the test axle shall be between 40 and 120°F (4 and 49°C).

6.2.7 If a drop test axle fails, a retest shall be permitted when it can be determined that the failure is caused by a mechanical condition of the drop-test machine (this condition must be corrected before a retest can be performed) or when it can be determined a mechanical flaw in the test axle was the reason for failure.

6.2.8 *Drop-Test Machine*—The anvil of the drop-test machine shall be supported on twelve springs, as shown in the AAR drawings,[8] shall be free to move in a vertical direction, and shall weigh 17 500 lb (7938 kg). The radius of the striking face of the tup and of the supports shall be 5 in. (127 mm).

6.2.9 *Number of Drop Tests*—One axle, selected by the purchaser's inspector from each heat of steel, shall be drop tested; or the manufacturer may furnish a report of a drop test made previously on the same heat.

6.2.10 The manufacturer may substitute Grade F for Grade U axles. Such axles must be marked Grade F and comply with specification requirements for Grade F axles.

6.3 *Tension Tests*:

6.3.1 Grade U axles (AAR classes B through E) shall be held pending tensile test results and be released if the results conform to.

6.3.2 The yield point in Table 5 for Classes B through E may be determined as outlined in 7.1.4.

6.3.3 Tension test specimens shall be procured as indicated in 7.1.7.

6.3.4 One tension test is required for each untreated heat of axles for qualification of the heat.

6.3.5 If the results of the tension test do not conform to the requirements specified because a flaw developed in the test specimen during testing, a retest is permitted as indicated in 11.1.

6.3.6 If the results of the mechanical tests of any Grade U lot of axles do not conform to the requirements specified, the axle having the prolongation from which the tension specimen was taken will be drop tested. Failure of the drop test axle is covered in 6.2.7.

[8] Section B of the AAR Mechanical Division *Manual of Standards and Recommended Practices*; see Footnote 2.

7. Mechanical Requirements and Tests for Heat Treated Axles

7.1 *Tension Tests*:

7.1.1 Grades F, G, and H axles shall conform to the requirements in Table 6.

7.1.2 The classification of axle forgings by size shall be determined by the finished diameter of the journal.

7.1.3 The diameter of the test prolongation of axle forgings shall be determined by the forged diameter of the journal.

7.1.4 The yield point in Table 6 for Grade F may be determined by the drop of the beam or halt of the gage of the testing machine or, by use of dividers. Where a definite yield point is not exhibited, the yield point method in 7.1.5 shall be used.

7.1.5 The yield point prescribed in Table 6 for Grades G and H axles shall be determined by a strain gage or extensometer reading to 0.0002 in. (0.005 mm). Yield point may be defined as the stress at 0.6 % total strain under load or as the stress at 0.2 % offset. The method described in Methods and Definitions A 370 shall be followed. After the yield point has been passed the extensometer may then be removed and the test continued to determine the tensile strength.

7.1.6 Tests shall be made only after final heat treatment.

7.1.7 *Tension Test Specimens*:

7.1.7.1 Tension test specimens shall be taken from the test prolongation or an axle in accordance with the provision in 7.2.

7.1.7.2 Unless otherwise specified, the axis of the specimen shall be located at any point midway between the center and surface of the axle or full-sized prolongation and shall be parallel to the axis of the axle.

7.1.7.3 The tension test specimen shall be machined to the form and dimensions shown in Fig. 5 of Methods and Definitions A 370 covering the standard round tension test specimen with a 2-in. (50.8-mm) gage length.

7.2 *Prolongation for Test*:

7.2.1 For test purposes, prolongations shall be attached to at least 5 % of the axles in each size classification of each heat in each heat-treating lot.

7.2.2 If axles with prolongations have been expended then axles may be used for test procurement.

7.3 *Microscopical Test*—For heat-treated axles (Grades F, G, and H):

7.3.1 A specimen, representing each size classification of each heat in each heat-treatment lot, shall be taken for microscopical test from the tension test specimen. This section for microscopical test shall be cut from the large undistorted portion of the tension test specimen in such a way as will give a face transverse to the axis of the axle.

7.3.2 The face shall be polished practically free of scratches and shall be etched to define the microstructure. The specimen shall be examined under a magnification of 100 diameters.

7.3.3 The entire specimen shall show a uniform, fine-grained structure, and shall have a grain size of 5 or finer as measured in accordance with Test Methods E 112.

7.4 *Number of Tests*:

7.4.1 Unless otherwise specified by the purchaser, mechanical tests for grades and sizes shown in Table 6 shall be made upon heat-treated axles as covered in 7.4.2 and 7.4.3.

TABLE 3 Drop Test Requirements for AAR Plain Bearing Axles

A.A.R. Class	Size of Journal, in. (mm)	Diameter of Axle, at Center, in. (mm)	Length of Axle, in. (mm)	Height of Drop, ft (m)	Number of Blows	Maximum Permanent Set, in. (mm)
A	3¾ by 7 (95.2 by 177.8)	4¼ (108.0)	83¼ (2115)	18 (5.49)	5	8¾ (222.2)
		4⅜ (111.1)		19 (5.79)		8⅜ (212.7)
B	4¼ by 8 (108.0 by 203.2)	4¾ (120.6)	84¼ (2140)	22½ (6.86)	5	7½ (190.5)
		4⅞ (123.8)		23½ (7.16)		7¼ (184.2)
C	5 by 9 (127.0 by 228.6)	5⅜ (136.5)	86½ (2197)	29 (8.94)	5	6¼ (158.8)
		5½ (139.7)		30 (9.14)		6 (152.4)
D	5½ by 10 (139.7 by 254.0)	5⅞ (149.2)	88½ (2248)	34½ (10.51)	5	5½ (139.7)
		6 (152.4)		36 (10.97)		5¼ (133.4)
E	6 by 11 (152 by 279.4)	6⁷⁄₁₆ (163.5)	90¾ (2305)	41½ (12.65)	5	4¾ (120.6)
		6⁹⁄₁₆ (166.7)		43 (13.11)		4½ (114.3)
F	6½ by 12 (165.1 by 304.8)			see 6.14		
G	7 by 12 (177.8 by 304.8)			see 6.14		

TABLE 4 Drop Test Requirements for AAR Roller Bearing Axles

A.A.R. Class	Size of Journal, in. (mm)	Diameter of Axle, at Center, in. (mm)	Length of Axle, in. (mm)	Height of Drop, ft (m)	Number of Blows	Maximum Permanent Set, in. (mm)
B	¼ by 8 (108.0 by 203.2)	4¾ (120.6)	83 (2108)	22½ (6.86)	5	7⅜ (187.3)
		4⅞ (123.8)		23½ (7.16)		7⅛ (181.0)
C	5 by 9 (127.0 by 228.6)	5⅜ (136.5)	84⅞ (2156)	29 (8.94)	5	6⅛ (155.6)
		5½ (139.7)		30 (9.14)		5⅞ (149.2)
D	5½ by 10 (139.7 by 254.0)	5⅞ (149.2)	86⅛ (2188)	34½ (10.51)	5	5⅜ (136.5)
		6 (152.4)		36 (10.97)		5⅛ (130.2)
E	6 by 11 (152 by 279.4)	6⁷⁄₁₆ (163.5)	88 (2235)	41½ (12.65)	5	4½ (114.3)
		6⁹⁄₁₆ (166.7)		43 (13.11)		4⅜ (111.1)
F	6½ by 12 (165.1 by 304.8)			see 6.14		
G	7 by 12 (177.8 by 304.8)			see 6.14		

TABLE 5 Tensile Requirements For Nonheat-Treated Axles

Grade	Tensile Strength				Yield Point Minimum		Elongation in 2 in. or 50 mm Min, %	Reduction of Area Min, %
	Minimum		Maximum					
	psi	MPa	psi	MPa	psi	MPa		
U	85 000	585	135 000	930	40 000	275	14	25

7.4.2 Where batch-type furnaces are used, one test per grade per heat per size classification is required, but each test shall represent no more than 70 axles. The axles represented by this test shall be called a heat-treatment lot.

7.4.3 Where continuous heat-treating furnaces are used, one test per grade per heat per size classification is required, but each test shall represent no more than 70 axles. The axles represented by this test shall be called a heat-treatment lot.

7.4.4 If any test specimen fails because of a mechanical condition of the testing apparatus it may be discarded and another specimen taken.

8. Dimensional Tolerances

8.1 *Length and Diameter*:

8.1.1 For plain-bearing axles, the overall length shall not be less than the specified minimum length nor more than ⅛ in. (3.2 mm) over.

8.1.2 For passenger-car roller-bearing axles ordered to finished length, the overall length shall not be less than the specified minimum length nor more than ⁷⁄₁₆ in. (1.6 mm) over.

8.1.3 For all axles ordered for finished-end facing by the purchaser the overall length shall range from ⅛ in. to ¼ in. (6.4 mm) over the specified minimum length.

8.1.4 For freight-car roller-bearing axles ordered to final length, the overall length shall not vary more than ⁷⁄₁₆ in. (1.6 mm) over or under the specified length.

8.1.5 For any other axles ordered to final length and not covered by the above classifications the overall length shall not be less than the specified minimum length nor more than ⅛ in. (3.2 mm) over.

8.1.6 The specified minimum length shall be the nominal overall final length less any allowable tolerances.

8.1.7 Rough-machined journals and wheel seats shall be ⅛ to ¼ in. (3.2 to 6.4 mm) over the finished diameters and ⅛ to ¼ in. of metal shall be allowed longitudinally at each change of cross section for finish machining.

8.1.8 The smooth-machined body shall be to the specified size with no more than ⅛ in. (3.2 mm) over on the diameters and shall have no more than ⅛ in. allowance longitudinally at each change of cross section.

9. Workmanship, Finish, and Appearance

9.1 The axles shall conform to the size and shape specified by the purchaser. Centering shall be a standard 60° with clearance drilled for lathe center points.

9.2 Axles shall be machined to a smooth-machined finish between wheel seats. The wheel seats and journals shall be rough machined. The rough machining shall be free from objectionable ridges and chatter marks.

9.3 *Finish*—The axles shall be free of injurious imperfections. The machining shall be done in a workmanship manner to the contour specified.

9.4 The interpretation of injurious imperfections in axles shall comply with Annex A1 to this specification.

TABLE 6 Tensile Requirements for Carbon Steel Heat-Treated Axles

Grade	Size, in., Solid Diameter or Thickness				Tensile strength, min		Yield Point, min		Elongation in 2 in. or 50 mm, min, %	Reduction of Area, min, %
	Over		Not Over							
	in.	mm	in.	mm	psi	MPa	psi	MPa		
F (double normalized and tempered)	. . .	. . .	8	203	88 000	605	50 000	345	22	37
	8	203	12	305	86 000	590	48 000	330	21	35
	12	305	14	356	84 000	580	46 000	320	20	33
G (quenched and tempered)	. . .	. . .	4	102	90 000	620	55 000[A]	380	20	39
	4	102	7	178	85 000	585	50 000[A]	345	20	39
	7	178	10	254	85 000	585	50 000[A]	345	19	37
	. . .	. . .	. . .	. . .	82 500	570	48 000[A]	330	19	36
H (normalized quenched and tempered)	. . .	. . .	7	178	115 000	790	75 000[A]	520	16	35
	7	178	10	254	105 000	725	65 000[A]	450	18	35
	. . .	. . .	. . .	. . .	100 000	690	60 000[A]	415	18	35

[A] See 7.1.5.

10. Ultrasonic Inspection

10.1 *Equipment*:

10.1.1 Equipment shall be as follows:

10.1.1.1 The instrument used must be a pulse echo type.

10.1.1.2 The instrument shall be operated at a 2¼-MHz frequency for both penetrability and discontinuity detection for heat-treated, and at 1 MHz for nonheat-treated axles.

10.1.1.3 The instrument may use various transducers, namely, quartz 1 in. (25.4 mm) square or 1⅛ in. (28.6 mm) round, or barium titanate ¾ in. (19.1 mm) to 1 in. round. The transducer type is at the option of the axle manufacturer. Other transducers of similar response capability as those described may be used.

10.2 *Time of Inspection*—Inspection shall be made after axle ends are machined and centered, or at any subsequent stage of processing.

10.3 *Instrument Sensitivity and Scanning*:

10.3.1 *Instrument Sensitivity*:

10.3.1.1 The instrument sensitivity shall be adjusted to produce an indication of the amplitude specified below, from a reference test block manufactured from a Grade F axle forging having a ⅛-in. (3.18-mm) diameter, 1-in. (25.4-mm) deep, flat-bottom hole drilled perpendicularly to and at a distance of 15 in. (381 mm) from the test end face of the axle section. The reference test blocks shall have a surface finish of 80 to 125 µin. (2.03 to 3.18 µm). Alternate references that give equivalent sensitivity may be used as defined in 8.5.1.

	Indication Amplitude, % FSH
Heat-treated axles	20
Nonheat-treated axles	40

10.3.1.2 At the sensitivity established in 10.3.1.1 the instrument shall detect in reference axles, either heat-treated or nonheat-treated, a flat-bottom hole of the size and distance specified in the table below.

Minimum Size (Flat-Bottom Holes) Detectable at Various Distances from End Faces

	Test Distance to 15 in. (381 mm)	Test Distance 15 to 30 in. (381 to 762 mm)	Test Distance over 30 in. (762 mm)
Heat-treated axles	⅛ in. (3.18 mm)	¼ in. (6.35 mm)	⅜ in. (9.52 mm)
Nonheat-treated axles	¼ in. (6.35 mm)	⅜ in. (9.52 mm)	¾ in. (19.05 mm)

10.3.2 *Scanning*:

10.3.2.1 Scanning shall be performed from both end faces, which shall have a surface finish not exceeding 125-µin. (3.18-µm) finish. The scanning shall include the maximum end face area obtainable by manual or automated inspection.

10.3.2.2 During scanning the amplitude of the indication from the end face opposite the search unit shall be monitored and the amplitudes of all discontinuity indications shall be evaluated with respect to the distance from the test surface (see 10.3.3 and 10.5.2).

10.3.3 *Distance-Amplitude Correction*— The amplitude of an ultrasonic indication must be considered in relation to its distance from the testing surface to evaluate its significance. This can be accomplished by an electronic device or by distance - amplitude curves (DAC), which are described in 10.5.2.

10.4 *Rejection*:

10.4.1 *Longitudinal Penetration*—Axles that do not produce a 40% FSH minimum back reflection from the end face opposite the search unit shall be rejected or made acceptable by heat treatment.

10.4.2 *Discontinuity Test*—The axle shall be rejected if the amplitude of any discontinuity indication exceeds the indication levels obtained from the flat-bottom holes listed in the table under 10.3.1.2, considering the distance - amplitude correction as described in 10.3.3.

10.5 *Additional Information*:

10.5.1 *Alternative Reference Standards*— Alternative references may be used to establish the test sensitivity if they are cross referenced with the reference test block described in 10.3.1.1. For example, alternative references for heat-treated axles that give equivalent sensitivity: (*1*) a 1-in. (25.4-mm) indication from a No. 1 series "A" Alcoa block, and (*2*) a 1½-in. (38.1-mm) indication from an ASTM Practice E 127 block No. 1-0300.

10.5.2 *Distance-Amplitude Correction*— The amplitude of an ultrasonic indication from a given discontinuity size varies with its distance from the test surface. To compensate for this effect, a distance-amplitude relationship is employed. The

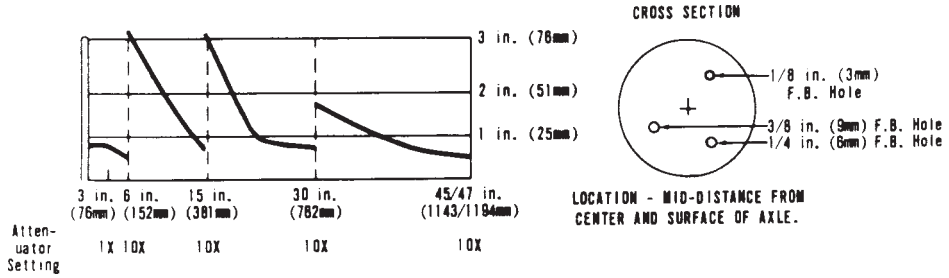


FIG. 1 Typical Distance-Amplitude Curve for a Heat-Treated Axle (as Determined with a Sperry Reflectoscope, Type UM Using a 1⅛-in. (28.6-mm) Diameter 2.25-MHz Quartz Transducer)

relationship can be established by an electronic device or by curves. Because the distance-amplitude relationship is influenced primarily by the ultrasonic transducer and instrument, it is necessary to relate this factor to the specific equipment used. Appropriate distance-amplitude curves shall be developed. Typical examples are shown in Fig. 1 and Fig. 2 as related to the axle in Fig. 3.

10.5.3 *Spurious Ultrasonic Indications from Contour Variations*—Because an axle varies in cross section it is possible to produce spurious indications, particularly at changes of cross section. These must be recognized, and are not reason for rejection. It is not practical to define these indications in the specification, but the competent operator or technician will recognize these spurious indications as responses from axle contours.

10.5.4 *Near-Field Resolution*—It should be recognized that detection of discontinuities near the test surface is limited by the ultrasonic test frequency. In the case of heat-treated axles, this is approximately 1 in. (25.4 mm) from the test surface.

11. Retest

11.1 If the results of the mechanical tests of any lot do not conform to the requirements specified because a flaw developed in the test specimen during testing, a retest shall be allowed if the defect is not caused by ruptures, cracks, or flakes in the steel.

11.2 If the results of the mechanical tests of any lot do not conform to the requirements specified, the axles may be retreated, but not more than three additional times, and retests shall be made in accordance with Section 7.

12. Inspection

12.1 Inspection of the axles shall be made as agreed upon by the purchaser and seller as part of the purchase contract.

12.2 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy him that the material is being produced and furnished in accordance with this specification. Mill inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations. All tests and inspections shall be made at the place of manufacture, unless otherwise agreed to.

13. Rejection and Rehearing

13.1 Any axle that fails to meet the requirements of this specification shall be rejected.

13.2 Axles that show injurious imperfections subsequent to acceptance at the manufacturer's works will be rejected and the manufacturer shall be notified.

13.3 Samples tested in accordance with this specification that represent rejected material shall be preserved for 14 days from the date of the test report. In case of dissatisfaction with the results of the test, the manufacturer may request a rehearing within that time.

14. Certification

14.1 Upon request of the purchaser in the contract or order, a manufacturer's certification that the material was manufactured and tested in accordance with this specification together with a report of the test results shall be furnished at the time of shipment.

15. Marking

15.1 Axles shall be legibly cold stamped with steel stamps with letters and figures not less than ¼ in. (6.4 mm) high in accordance with the requirements shown in Fig. 4.

15.2 In addition to the markings required in 15.1 and Fig. 4, bar code tags may be applied to the axles. If these tags are applied, it is recommended that bar code 39 be used. The size and location of the tags, as well as the information to be included, shall be agreed upon by the purchaser and manufacturer.

16. U.S. Government Procurement

16.1 When specified in the contract or purchase order, material shall be preserved, packaged, and packed in accordance with the requirements of MIL-STD-163. The applicable levels shall be as specified in the contract or order. Marking for shipment of such material shall be in accordance with Fed. Std. No. 123 for civil agencies and MIL-STD-129 for military agencies.

17. Keywords

17.1 axles; rail applications

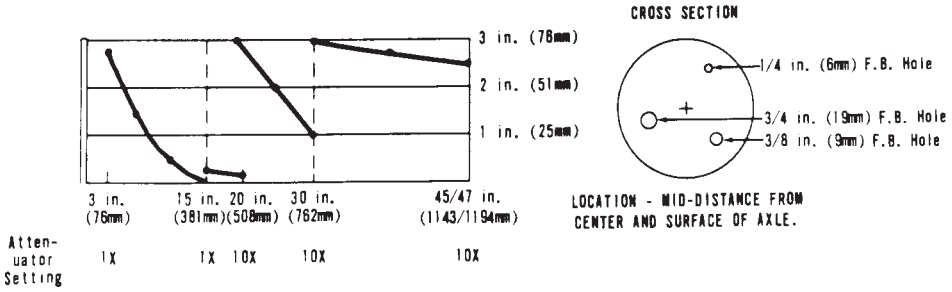


FIG. 2 Typical Distance-Amplitude Curve for an Untreated Axle (as Determined with a Sperry Reflectoscope, Type UM Using a 1⅛-in. (28.6-mm) Diameter 1.00-MHz Quartz Transducer)

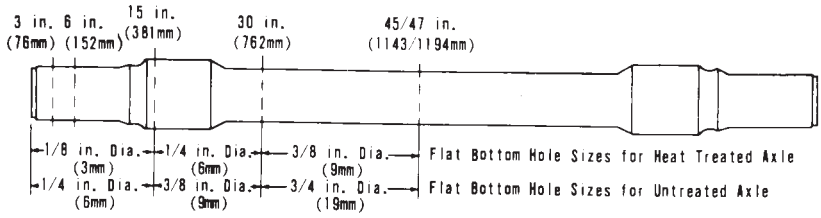
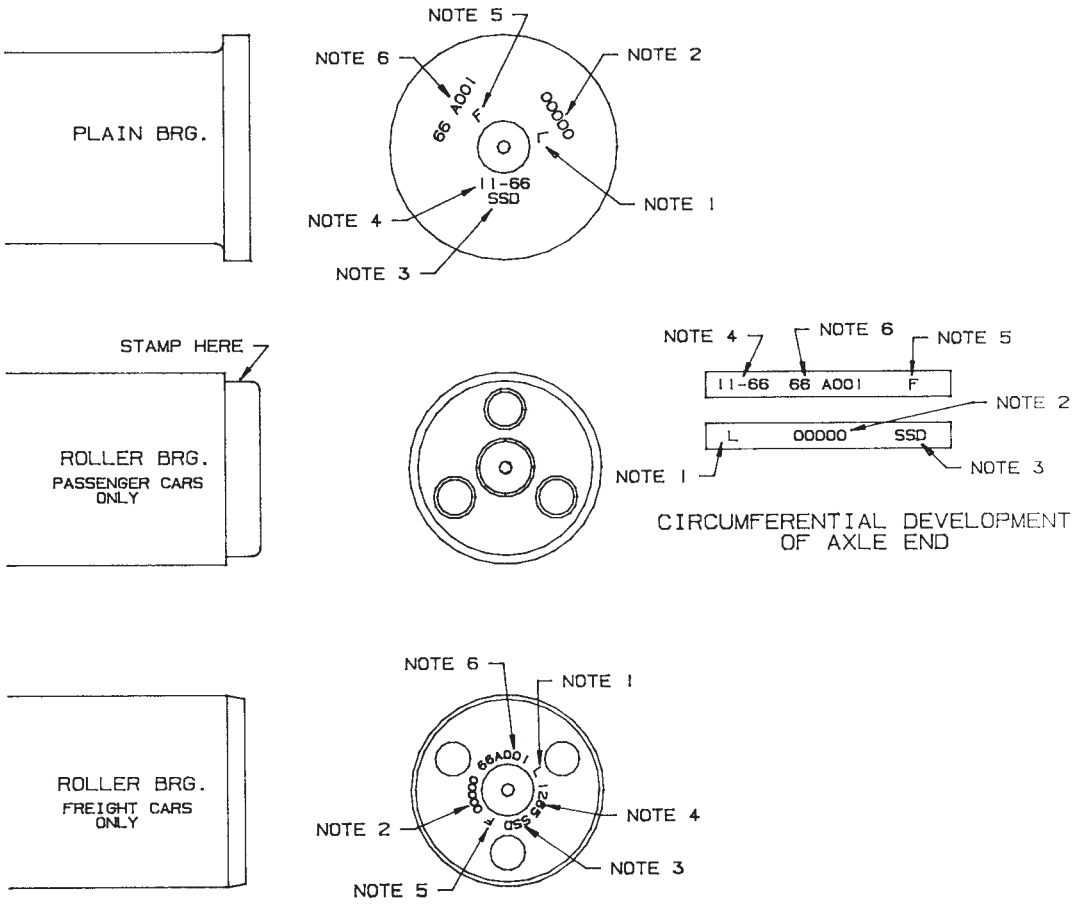


FIG. 3 Showing Location of Reference Holes in Axle



NOTE 1—*Laboratory Acceptance Stamp:* For use by purchaser to signify acceptance of axles so marked prior to shipment by producer.
NOTE 2—Serial number.
NOTE 3—Manufacturer's name or brand:

SSD	Standard Steel, Burnham, Pa
JAW	Standard Forged Products, Johnstown, Pa
MRF	McKees Rocks Forgings, McKees Rocks, Pa
DDAP	Dneprovsky Iron & Steel, Ukraine
HM	Huta 1 Maja, Gliwice, Poland
TW	Trenton Works Lavalin Inc., Trenton, Nova Scotia
CB	Cobrasma, Osasco, Brazil
MW	Mafersa, Cacapava, Brazil
SPT	Firth-Rixson, Rotherham, England
CF	ASFOR, Dunkerque, France
V	ASFOR, Valenciennes, France
SMI	Sumitomo, Osaka, Japan
SW	SWASAP, Germiston, S. Africa
L	Terni, Lovere, Italy
NOR	Jingzi-Norinco Taiyuan, China

NOTE 4—Month and year made.
NOTE 5—Grade of axle:

U	untreated
F	double normalized and tempered
G	quenched and tempered
H	normalized, quenched, and tempered

NOTE 6—Heat number.

GENERAL NOTES

All marks will be deeply and legibly stamped with characters not less ¼ in. high and those for freight car roller bearing axles located adjacent to the periphery of the centering hole. Manufacturers must finish one end of axle for stamping. All elevations or irregularities should be filed or ground after stamping. The above are the minimum marking requirements but the locations on individual items may vary from that illustrated.

FIG. 4 Standard Axle Marking

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement shall apply only when specified by the purchaser. Details shall be agreed upon by the manufacturer and the purchaser.

S1. Macroscopical Tests

S1.1 The prolongation from the largest axle in each heat shall be sawed normal to the axis of the axle and shall then be split longitudinally. The transverse and the longitudinal face shall be etched for macroscopical examination. Reference shall be made to Method E 381.

ANNEX

(Mandatory Information)

A1. INTERPRETATION OF IMPERFECTIONS CONSIDERED INJURIOUS IN AXLES

A1.1 General

A1.1.1 The conditions that have been most difficult for inspectors to evaluate are light lines visible to the normal unaided eye, variously described as actual seams, hairlines, stringers, shadow seams, ghost lines, etc., which appear after the axles have been finish machined and burnished or ground. It is, therefore, advisable to describe these conditions in more detail.

A1.1.2 The interpretation of injurious imperfections as enumerated below is not to be considered as precluding other unforeseen or objectionable conditions not specifically listed. The right of the purchaser is reserved to reject temporarily such axles and make final settlement on the basis of further negotiations between representatives of the manufacturer and the purchaser who are especially qualified to decide such questions.

A1.1.3 Any transverse or circumferential seams, cracks, or laps of indeterminate depth on the axle surfaces other than the discolorations listed in A1.1.4 regardless of their location, are considered to be injurious and are cause for rejection without further machining.

A1.1.4 Ghost lines, shadow marks, or other similar discolorations, visible to the normal unaided eye that are not actual separations in the metal are not considered injurious regardless of location.

A1.1.5 Any longitudinal discontinuity, variously termed hairline, stringer, or fine seam, in machined fillets is considered to be injurious and is cause for rejection without further conditioning.

A1.2 Journals and Dust Guards

A1.2.1 *Plain-Bearing Axles*

Fine longitudinal discontinuities on the finished machined surfaces, variously termed hairlines, stringers, or fine seams, are not considered injurious if they meet the following conditions:

A1.2.1.1 Must not extend into fillets and must not have sharp edges. Journals must never be cleaned with a coarse abrasive or polished with emery under heavy pressure. Streaks, scratches, and some taper may result. The abrasive may become embedded in the steel and contribute to a “hot box.” Polishing may be done with artificial abrasive cloth (No. 180 grit or finer, free from ridges, selvage, etc.) using plenty of oil on a wooden block hollowed out to fit the journal.

A1.2.1.2 Must not be over ½ in. (12.7 mm) long individually.

A1.2.1.3 Total length of such imperfections, ¼ in. (6.4 mm) to ½ in. (12.7 mm) long, must not exceed 1½ in. (38.1 mm) in any one end of the axle.

A1.2.1.4 Within any 3-in. (76.2-mm) length there may not be more than two such imperfections, ¼ in. (6.4 mm) to ½ in. (12.7 mm) long, in line with each other in any one end of axle.

A1.2.2 *Roller-Bearing Axles*

Fine longitudinal discontinuities on the finished (burnished or ground) surfaces variously termed hairlines, stringers, or fine seams are not considered injurious if they meet the following conditions:

A1.2.2.1 Must not extend into fillets.

A1.2.2.2 Must not be over ¾ in. (19.1 mm) long individually in the journal nor ½ in. (12.7 mm) long individually in the dust-guard seat.

A1.2.2.3 Total length of such imperfections over ¼ in. (6.4 mm) long must not exceed 2 in. (50.8 mm) in any one end of axle.

A1.2.3 *Refinishing*

Burnished plain journals showing imperfections in excess of the limitations outlined in A1.2.1 may be reconditioned by refinishing to a diameter not smaller than 0.020 in. (0.5 mm) under the nominal diameter. If, after refinishing the axles meet the requirements of A1.2.1 above they may be considered acceptable.

A1.3 Wheel and Gear Seats

A1.3.1 *Freight Car Axles* (*Plain and Roller Bearing*)—Longitudinal seams in wheel seats of freight car axles are not considered injurious if they meet the following conditions:

A1.3.1.1 Must not extend into the dust guard or body fillets.

A1.3.1.2 Must not be over 2 in. (50.8 mm) long individually.

A1.3.1.3 Total length of such imperfections, ¼ in. (6.4 mm) to 2 in. (50.8 mm) long, must not exceed 4 in. (102 mm) in any one end of axle.

A1.4 All Other Axles

A1.4.1 Longitudinal discontinuities on the finished-machined surface of wheel and gear seats, variously termed hairlines, stringers, fine seams, tight seams, surface imperfections, etc., are not considered injurious if they meet the following conditions:

A1.4.1.1 Must not extend within 1½ in. (38.1 mm) of either end of wheel or gear seat.

A1.4.1.2 Must not be over ½ in. (12.7 mm) long individually.

A1.4.1.3 Total length of such imperfections, ¼ in. (6.4 mm) to ½ in. (12.7 mm) long, must not exceed 3 in. (76.2 mm) in any one end of axle.

A1.5 Areas Between Wheel (and Gear) Seats (Body)

A1.5.1 *Machined Bodies*

Longitudinal discontinuities on the finished surfaces, variously termed hairlines, stringers, or fine seams, are not considered injurious if they meet the following conditions:

A1.5.2 Must not extend into fillets adjacent to wheel or gear seat.

A1.5.3 Must not be over ½ in. (12.7 mm) long individually.

A1.5.4 Total length of such imperfections, ¼ in. (6.4 mm) to ½ in. (12.7 mm) long, must not exceed 1½ in. (38.1 mm) in any 12 in. (305 mm) of body length.

A1.5.5 Axles containing longitudinal discontinuities in the body in excess of those described in A1.5.3 and A1.5.4 above may be reconditioned by grinding or machining provided the diameter is not reduced below the specified limit.